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THE TRAINING OF AN ELECTROCHEMIST.

AT the meeting of the German Electrochemical Society in Zürich, last August, Professor Richard Lorenz,* at the request of the Society, read a paper on the kind of training which is desirable for an electrochemist. The paper contains much which is suggestive in reference to the training of chemists in general, and calls attention to certain defects in the present method, especially as applied in many of the German universities.

Lorenz first raises the question as to whether electrochemists are entitled to recognition as representing a separate and distinct branch of science, and, notwithstanding the fact that they have not yet received such recognition in all the schools, answers the question, of course, in the affirmative. The battle in reference to the existence and recognition of electrochemistry is, in most places, at an end. Its chief enemy is the one-sided manner in which chemists, until recently, have been trained; and this one-sided method of training still obtains in some universities. We know, to-day 'that a chemical doctor well trained in all directions' is often nothing but a special organic chemist. Even if in some cases the candidate has learned a little analytical chemistry in order to be able to pass certain examinations outside of the university, he knows absolutely nothing of that fundamental branch of science—physical chemistry—and his knowledge of inorganic chemistry is so fragmentary that it cannot be called scientific—of the science of inorganic chemistry he knows essentially nothing.

It is quite different at certain polytechnic institutions where inorganic chemistry is constantly introduced in connection with technical chemistry and metallurgy.

Since electrochemistry, as is well known, is one of the best developed branches of physical chemistry, the electrochemist should be trained in physics and in chemistry. Organic chemists should also know much more physics than is usually required of them.

Electrochemistry is also very closely connected with inorganic chemistry, and the rise of physical chemistry and electrochemistry in Germany has reawakened an interest in inorganic chemistry, which had almost entirely disappeared. Modern electrochemistry is an exact science, and rests on a mathematical basis. Every electrochemist must, therefore, be trained in the elements of the higher mathematics, and be able to use the differential and integral calculus. Later he must apply thermodynamics and chemodynamics to the problems as they arise. It is not until mathematics is applied to special problems that its significance is appreciated by the investigator of nature.

It is difficult to lay too much stress on the importance for an electrochemist of a general training in physics. He should be trained first of all in mechanics, then in sound that he may become familiar with the conception of wave-motion, also in heat, light, electricity and magnetism.

The physicist, in training a skilful electrochemist, should not ask "What use can he make of my knowledge?" and he should not adapt his teaching to special needs. The electrochemist, as well as the practical chemist, can use all physics. They may have to do with the magnetic properties of the atoms, or with heat phenomena, or with photometric relations, or with the kind and nature of the vibrations in an ozonator, or with fusion, evaporation and specific heats in the electric furnace. If the physicist were to consider simply the 'needs of the electrochemist,' he would teach him simply the chapters which pertain to electrical measurements. This would be a serious error and would retard the development of electrochemistry along broad

*Ztschr. elect. Chem., 7, 201.

and general lines. The need of the electrochemist is for the broadest possible development in the science of physics.

Analytical chemistry is of fundamental importance for the electrochemist. He should be able to make more or less complex analysis not only accurately, but rapidly. Speed in carrying out an analysis is often a necessity.

Inorganic chemistry is still taught but little at the German universities, and this is, of course, fundamental for the electrochemist. Some little inorganic chemistry is taught under the head of 'general chemistry.' In other places some lecture experiments are shown, and equations written, showing the transformations of substances. In other places inorganic chemistry is dealt with from the standpoint of the modern theory of ions. But in the last decade inorganic chemistry has developed as rapidly and made as great strides as theoretical chemistry. Thus, the vast amount of knowledge which we have in reference to the formation and decomposition of double salts, the beautiful experiments in the field of complex compounds, the extension of our science to the rare gases and rare earths, the reactions of substances at high temperatures as studied by the French school, the transformation temperatures and, finally, the fundamental relations of all phenomena to the Periodic System, are seldom dealt with. We need a place in which these matters can be *really systematically discussed* and brought to their attention. We should teach the students fewer formulas and more about the *real knowledge of the properties of all the elements and compounds.*

We know from the lectures of Van't Hoff on 'The Increasing Importance of Inorganic Chemistry,' and of Hittorf on 'The Necessity of Establishing Special Chairs for Inorganic Chemistry in the German Universities,' that the chairs of inorganic chemistry have been occupied almost exclusively by organic chemists, whose interest and indeed whose knowledge were not in this field. As co-editor with Küster of the *Zeitschrift für anorganische Chemie*, I have had the very best opportunity to observe how great has been the growth in this field. If any one should think that the reason for desiring new chairs of inorganic chemistry to be established is in any way connected with the desire that certain individuals should have full professorships in inorganic chemistry, he has not obtained his information from the proper source.

In reference to the training of the electrochemist in organic chemistry, that is already amply provided for, and nothing further need be said concerning it. The electrochemist should also study as subordinate subjects mineralogy, crystallography, geology, etc.

Lorenz then takes up the question as to how far the electrochemist should be familiar with mechanics, a knowledge of machines, mechanical drawing, etc. He recognizes the force of Ostwald's warning, that the student should not have too many subjects, but under present conditions electrochemists, in out-of-the-way places, may have to fill so many rôles that a knowledge of these mechanical matters is often a necessity.

In reference to the special electrochemical training; instruction should be given, as Knorre has already pointed out, in general and technical electrochemistry, in general physical chemistry, as well as in thermochemistry, chemical dynamics, organic electrochemistry, chemical thermodynamics, etc. The student should be so trained in mathematics that these subjects can be dealt with mathematically. The best means to train and develop an electrochemist, in general, is the carrying out of a scientific investigation, as Ostwald has already maintained.

Lorenz then takes up the discussion of

the work which should be done by the electrochemist in the laboratory, and finally decribes the training which the students in the Polytechnic Institute in Zürich receive. The point which is of chief interest here is that *mathematics is required for every chemist*, and physics is introduced in the broadest way into the course of every chemist.

The scientific importance of this address is much greater than would be implied by its title. The question arises whether much that was said by Lorenz does not apply to other branches of science or, perhaps, to all, although it is true that some of the natural sciences, chiefly on account of the relative complexity of the phenomena dealt with, are not yet sufficiently advanced to enable the mathematical methods to be extensively applied to them, yet they are all rapidly approaching that stage which we may describe as the mathematical.

Take as an example the science of chemistry. Physics, the furthest developed of all the natural sciences, has long since become an exact or mathematical science. It has been only a short time since a student could get on fairly well in most branches of chemistry without any knowledge of the higher mathematics. But how different to-day? A chemist now who is not familiar with the calculus can have no adequate conception of the theoretical side of his science, as Van't Hoff and others have repeatedly pointed out. In inorganic chemistry, at least in its latest developments, the calculus is absolutely essential, since inorganic chemistry is touched at all points by physical chemistry, and who can know anything of physical chemistry without the calculus. Take on the other hand organic chemistry. There are certain very important phases of this subject into which the higher mathematics has not yet entered; but in the study of the velocity of organic reactions, of the chemical dynamics and statics of such reactions, not only the calculus is required, but also a fair knowledge of thermodynamics. In physical chemistry a knowledge of the higher mathematics and of physics is just as essential as a knowledge of chemistry itself, and thus it goes through the whole field of chemistry.

A student who starts out to-day to become a chemist without a good knowledge of physics and mathematics is hopelessly handicapped at the outset, no matter to what division of chemistry he may turn his attention.

In other branches of science we already see the dawn of the exact or mathematical period. Take physiology, one of the most complex of the biological sciences. Certain phenomena of life have already lent themselves to mathematical treatment, as is shown by the work of Loeb and others. The application of physical chemistry to physiology seems to mark the introduction of the mathematical method in dealing with the physics and chemistry of life.

Take morphology—the work of Davenport shows that even structure can be treated by the exact method, and makes it probable that the morphologist in the future will have to look to his higher mathematics.

Other branches of science might be cited, but these suffice to show how rapidly the mathematical method is coming to be applied to all scientific knowledge. *Perhaps the most distinguishing feature of scientific study at the beginning of the twentieth century is the introduction of the mathematical method into all those branches of knowledge which are sufficiently developed.*

One of the most important features, therefore, in scientific training to-day is a thorough course in the elements of the higher mathematics, and this should be followed in every case by an equally thorough course in physics. The student who is not thus equipped can never hope to pass

beyond empiricism, nor obtain any insight into the real meaning and relations of natural phenomena.

HARRY C. JONES.

APPROPRIATIONS FOR THE U. S. DEPARTMENT OF AGRICULTURE.*

THE passage of the agricultural appropriation act for the year 1901–1902 marks an epoch in the history of the development of the national Department of Agriculture. Not only does it carry the largest appropriation ever made for the Department and provide for future extension of its work in various lines, but it inaugurates a scheme for the partial reorganization of the scientific branches of its work. Three of the present divisions are raised to the grade of bureaus, and a number of other divisions are associated in one large Bureau of Plant Industry, corresponding in a general way to the present Bureau of Animal Industry.

Starting first as an appendix to the Patent Office for the distribution of seeds, the Department of Agriculture was formally organized in 1862 as an independent department in charge of a commissioner, and in 1889 was raised to the dignity of an executive department. The passage of the Hatch Act providing for agricultural experiment stations about that time increased its responsibilities and extended its field of usefulness.

The growth of the Department has been steady and uninterrupted. The importance of its work has been recognized by steadily increasing appropriations, and the relations maintained with the experiment stations furnish a means of carrying its investigations into every section of the country, in cooperation with these institutions, and serve to broaden its influence. As an institution for agricultural investigation it is now without a counterpart in any country, and there are few, if any, scientific institutions which include so large an aggregation of scientists and experts devoting their attention to investigations and research. The Department is coming to be generally recognized as one of the great scientific institutions, not alone in this country, but of the whole world. The formation of bureaus is a fitting step at this juncture, for it is a recognition of the growth which has been made and the need for a more compact form of organization. The creation of these four new bureaus, in addition to the Weather Bureau and the Bureau of Animal Industry, is a following out of the general divisions into which the subject of agriculture seems logically to fall, associating such lines of work as relate closely to each other and providing for the closest cooperation practicable among them.

The new Bureau of Plant Industry embraces the divisions of Botany, Vegetable Physiology and Pathology, Agrostology, Pomology, and Gardens and Grounds, and is under the directorship of B. T. Galloway. To this bureau has also been assigned the Section of Seed and Plant Introduction, together with the general supervision of the experiments in tea culture. A horticulturist will be added to the list of specialists, with the intention of developing the work of investigation along that line. From the standpoint of administration the arrangement will be an economy of time and will give greater opportunities for investigation to the chiefs of the divisions.

In recognition of the plan for a systematic survey of agricultural soils and for extension of the work in forestry, the divisions of Soils and Forestry receive bureau organizations and are raised to that designation. The fourth bureau provided for is the Bureau of Chemistry, to which additional scope will be given.

* From proofs of the 'Experiment Station Record,' Vol. XII., No. 9.